DOCUMENT RESUME

ED 252 181 IR 011 441

AUTHOR Metrowich, T. P.; And Others
TITLE Computers in Education; a Selection of Articles.
PUB DATE Jan 84
NOTE 16p.
PUB TYPE Collected Works - Serials (022) -- Journal Articles (080) -- Reports - Descriptive (141)
JOURNAL CIT South African Journal of Science; v80 p10-24 Jan 1984

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Computer Assisted Instruction; *Computer Managed Instruction; *Computers; Elementary Education; Foreign Countries; Higher Education; *Mathematics Instruction; *Science Instruction
IDENTIFIERS Computer Uses in Education; PLATO; *South Africa

ABSTRACT

Computer applications in South African schools are described in this five-paper collection of journal articles, which covers a range of projects from primary school and university elementary arithmetic to more sophisticated applications in physics, chemistry, and biochemistry. "Implementation of a System of Computer-Assisted Instruction in Arithmetic in Black Primary Schools in South Africa" (T. P. Metrowich and J. J. D. Roux) discusses the implementation of the TOAM system (a Hebrew acronym for test and practice) at five primary schools. In "Computer-Assisted Learning in the Primary School: A South African Example," P. Waker describes microcomputer use at the Sea Point Boys' Primary School in remedial spelling and enrichment programs. "Microcomputers, Conceptual Change and the Design of Science Instruction: Examples from Kinematics and Dynamics" (Peter W. Hewson) explores use of the microcomputer to address students' alternative conceptions of physical phenomena through diagnostic and remedial programs. The role of the computer in education is addressed by J. D. Bradley, G. Brink, and L. Glasser in "CAI: A Report to the Academy." In "Computer-Managed Instruction on the PLATO System," G. R. Delpierre explains use of the PLATO Learning Management System at the University of the Western Cape. All papers list references. (LMM)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

Computers in Education

On the following pages we present a selection of articles on how computers are being used in the classroom in South Africa. The examples described include uses in the primary school and at university, by the teachers of elementary arithmetic and of more sophisticated concepts in physics, chemistry and biochemistry. The emphasis is on what has been achieved so far with these machines, though some indications are given of what might be expected from computer-assisted instruction in the near future.

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
This document has been reproduced as received from the person or organization originating it.
Minor changes have been made to improve reproduction quality.
Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
L. Glasser
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

ED252181

IR011441

Implementation of a System of Computer-assisted Instruction in Arithmetic in Black Primary Schools in South Africa

T. P. Metrowich and J. J. D. Roux

A common problem in South Africa and, indeed, throughout the world, is the difficulty in understanding basic arithmetical concepts experienced by many children at primary school. One approach to the problem is the use of computers as part of an instructional system to improve the pupils' performance in arithmetic.

The TOAM (a Hebrew acronym for test and practice) system of computer-assisted instruction, originally developed at Stanford University, was adapted to Israeli needs and introduced in disadvantaged schools there seven years ago. The generosity of the C. S. Barlow Foundation has allowed the purchase from Israel of two identical computer systems, each consisting of 32 terminals, a small mainframe computer and printer. The computer program in arithmetic embodies the results of further research and development done by the Centre for Educational Technology (C.E.T.) in Tel Aviv, in the field of computer-assisted instruction. One of the systems has been installed in a specially prepared room at Molapo Technical Centre, Soweto. The other is housed in a 12-metre long mobile trailer.

The successful transplantation of any novel system into a different environment requires research to determine the adaptations that may be needed to ensure the success of the transplant. These two systems will therefore be used in a three-year research and development programme under the aegis of the Centre for Continuing Education of the University of the Witwatersrand. Some of the research objectives of this programme have already been documented.[1] For the purposes of the pilot study, one aim was to evaluate some of the claims made by the developers of the system with regard to the following:

- the importance of the teacher in the total TOAM instructional system;
- the ability of the system to evaluate the performance of the pupils in arithmetic;
- the effective use of the computer printout as a diagnostic tool by the teacher;
- strategies for the remediation of weaknesses as revealed by the computer;
- the effectiveness of the computer program in improving the performance of pupils.

The results reported in this article are necessarily preliminary in view of the short time that the pupils have been on the computer. The results of this pilot study have, however, given an indication of the direction in which the project should now proceed. Two classes of learners have been identified: the pupil at primary school and the adult learners attending literacy and numeracy courses at adult education centres in Soweto and elsewhere.

In this paper, the implementation of the TOAM system at five primary schools is discussed, and initial findings are presented, based on the results of tests applied to randomly selected teachers, and to pupils using the system.

Background

The use of the computer as an educational tool to enhance learning and teaching has been investigated in many countries for a number of years.[2-7] Of particular interest is the work done by Osin in Israel, using a modified version of the system developed by Professor Patrick Suppes of Stanford University in the 1960s. Israel experienced an influx of immigrants from Africa and Asia who came with little or no formal education at this time. Faced with the challenge of bringing the educational standard of these disadvantaged people to an acceptable level, the Israelis turned to modern technology, notably the computer. In seeking a solution to the problem, the C.E.T. decided to focus its attention on arithmetic initially, as it is a basic subject 'essential for the development of any country'.[7]

The selection of the methods developed by the team at Stanford was made by Dr Yona Peless in 1975, who concluded that the system developed by Suppes 'was the only one with proven results in the field of remedial instruction of arithmetic ... within an affordable price range'.[7] After modifications to the hardware (mainframe computer, terminals and printer) and the software, the Israeli research programme was started in Netivot in September 1977 under the name TOAM with 750 pupils at sixteen terminals.

In 1981 a small team headed by the then Regional Director of the Johannesburg Region of the Department of Education and Training (D.E.T.), visited Israel to study the TOAM operation at the Centre for Educational Technology. This team then recommended that the C. S. Barlow Foundation purchase a permanent and a mobile system for use in primary schools and adult education centres in Soweto. This led to the establishment of an applied research project at the University of the Witwatersrand.

The situation in Soweto

Pupils perform badly in arithmetic at primary schools in Soweto, as was the case in Israel. For example, the pass rates in

The authors are attached to the Computer-assisted Arithmetic Research Project, University of the Witwatersrand, Johannesburg 2001, South Africa.

BEST COPY AVAILABLE

mathematics among Std 5 pupils at eight primary schools in Soweto in 1982 were 1, 2, 16, 38, 59, 61, 69 and 94%, respectively.[12,13]

The TOAM instructional system was not designed to give tuition but rather as a test-and-practice medium. In the TOAM operation, the teaching is left in the hands of the teacher, who gives instruction in the various aspects of the syllabus and also undertakes remediation in those topics where the pupil has difficulties. The computer program provides the pupil with the facility to practice (in a ten minute session pupils are given between 30 and 50 exercises, depending upon their rate of working). The computer grades the child according to performance. The teacher then makes use of the results of the computer print-out to help pupils where needed.

In view of this, it is essential to the success of the project to determine the teachers' understanding of mathematical concepts and ability to act effectively in the classroom. Accordingly, 55 Std 2, 3 and 4 mathematics teachers were randomly selected from schools in Soweto and given various tests devised by the Human Sciences Research Council.[8,9] The results showed that 75% of the teachers had a better grasp of mathematical concepts than 90% of pupils starting Std 6. A further 18% were able to cope at the level of the average Std 6 pupil. The remaining 7% (four teachers) are responsible for Std 2 classes. While they may appear able to cope at this level, it is likely that any misconceptions they have about mathematics will be carried over to the pupils. The teachers' performance in the diagnostic tests indicated that they were able to cope with the basic arithmetical operations when applied to low numbers (< 1000). Division, however, causes some difficulty, as shown by the increasing percentage of errors scored by the group as the size of the numbers in the test items increased, e.g. 13% of errors in division with numbers less than one thousand and 27% errors with numbers up to one hundred thousand. The concept of vulgar fractions was not understood by 19% of the teachers, whereas almost half of the group (46%) experienced difficulty with decimal fractions.

In view of the importance of the teachers' contribution to the successful implementation of the TOAM instructional system, it is essential that these deficiencies on the teachers' part be remedied. Poor performance in division indicates that there is a lack of understanding of place value in larger numbers, with the result that decomposition and the use of zero are major obstacles in the division algorithms.

System description

Each system consists of a small mainframe computer with a disk-memory of 40 megabytes and 32 'dumb' (having very little internal memory) terminals. Each terminal has a small video monitor and the following touch-sensitive keys: digits 0 to 9; the relation signs $<$, $>$ and $=$; a decimal point; the 'minus' sign; screen 'advance' key; a red 'back' key and three teacher's 'control' keys. An instructor's terminal with standard keyboard and printer complete the hardware.

The software program in TOAM is based on the work of Suppes and incorporates the concepts of mathematical strands. A strand represents one content area within a syllabus. Each strand is a string of related items whose difficulty progresses from easy to hard. A computer program keeps records of the pupil's position and performance separately for every strand. By comparing a pupil's record of performance on the material in one strand with a preset performance criterion, the programme determines if the pupil needs more practice at the same level of difficulty within the strand, should move back to an easier level for remedial work, or has mastered the current concept and can move ahead to a more difficult level. The program then automatically adjusts the pupil's position to the correct level within the strand. The process of evaluation and adjustment applies to all strands and operates continuously.

Evenly spaced gradations in the difficulty level of the material allow positions within a strand to be matched to school grade placements by tenths of a year. Assigning grades in a specific subject can therefore be done by examining a pupil's position in the strand for that topic. Since performance in each strand is recorded and evaluated separately, the pupil may have a different grading in every strand of the syllabus.[15,16] Table 1 shows the topics and grades covered in each strand.

The TOAM arithmetic program has no exercises stored in the computer memory. The program that compiles the exercises includes algorithms which use random numbers on which each exercise is based. The exercises in each strand are graded by levels of increasing difficulty.

Each pupil is allocated a number which he enters at the terminal and then presses the green key. His name appears on the screen and on pressing the green key a second time he is presented with a series of exercises to complete. The first 12 sessions (each of 10 minutes' duration) are regarded as the testing stage.

During testing, the computer raises or lowers the pupil's position in the various strands to find the level at which the child can successfully solve (on average) two-thirds of the exercises presented. This method is based on an adaptation of Lord's ideas on tailored testing.[7] After the initial testing, each pupil attends a minimum of two 20 minute sessions per week.

The exercises in the TOAM software program are presented to the pupil in a random sequence as determined by the computer. Essentially this means that two pupils working at the same level of difficulty will not receive the same sequence of exercises in a given session at the terminal. A print-out at the end of each week gives the teacher information on the pupil's performance in each strand covered. Poor performance so identified can in principle then be worked on. However, for a variety of reasons, not the least of which are large classes and traditional lecture-type methods of teaching, individual instruction is not a practical possibility in Soweto at present. The teachers need guidance in this form of teaching. (The Israeli researchers found that only after two years' experience with the system could their teachers provide effective individualized instruction in the classroom.)

Familiarisation and implementation

In order to obtain the cooperation of the parents, teachers and pupils at the five schools involved in the probject, the following procedure was adopted:

1) School committee members were invited to use the system and to express their opinion on the proposed project.

2) The inspectorate and principals attended a briefing session on the aims of the project, during which their role was discussed and cooperation sought. Each principal made use of the computer for 2 or 3 sessions.

3) The teachers attended a course at which the operation of the system was ex-

Table 1. The topics in TOAM arithmetic.[7]

Strand number	Topic covered	Range*
1	Number systems	10 – 65
2	Addition and subtraction up to 20	10 – 28
3	Vertical addition	25 – 48
4	Vertical subtraction	26 – 56
5	Multiplication and division up to 100	20 – 35
6	Vertical multiplication	33 – 52
7	Vertical division	37 – 59
8	Mental arithmetic	32 – 69
9	Equations and operation laws	17 – 69
10	Measures and weights	40 – 66
11	Fractions	40 – 55
12	Decimal fractions and percent	50 – 69
13	Negative numbers	50 – 69
14	Word problems	20 – 69
15	Divisibility, factors and powers	44 – 69

*The range is given in grades, e.g. grade 25 represents the second year of school (grade 2) and the fifth month of that year assuming a 10 month school year. In the South African context, the grade equivalents are: Std 4 = grade 6, Std 3 = grade 5 and Std 2 = grade 4. Hence a grade placing of 55 would be equivalent to Std 3 and the fifth month of that year.

BEST COPY AVAILABLE

Table 2. Comparison of pupils' computer placings and Initial Evaluation Test results (n = 1198).

			Computer test			Initial eval. test		
			Sessions			Month written		
Std	School	Sex	12 Mean	20 Mean	Gain	February Mean	May Mean	Gain
2	A	F	23	25	2	49	55	6
		M	23	24	1	50	52	2
	B	F	23	25	2	44	45	1
		M	22	23	1	42	41	−1
3	C	F	25	27	2	49	48	−1
		M	25	27	2	49	47	−2
	D	F	25	27	2	49	51	2
		M	25	26	1	49	52	3
	E	F	26	28	2	51	53	2
		M	25	26	1	48	50	2
	B	F	25	27	2	45	49	4
		M	26	27	1	45	47	2
4	C	F	27	29	2	45	47	2
		M	28	29	1	45	47	2
	D	F	27	29	2	45	48	3
		M	27	29	2	45	49	4
	B	F	29	31	2	43	42	−1
		M	29	30	1	42	43	1

plained in detail. Each teacher then had 12 sessions on the computer as part of the familiarisation procedure. For the system to operate successfully, the teacher must be thoroughly conversant with the arithmetic syllabus and be able to do remedial work with individual pupils based on the diagnosis reflected in the computer print-out. The teacher is expected to prepare worksheets for pupils' use during remedial sessions covering all aspects of the arithmetic syllabus.

4) These teachers were then required to explain the operation of the system to their pupils.

Without exception, the committee members, principals and teachers reacted positively to the project. The 1200 pupils initially chosen for the experiment were first given the HSRC Initial Evaluation Tests in Mathematics for their respective standards.[10,11] They then attended sessions at the computer on prescribed days. The teacher was provided with a weekly print-out which detailed the performance of each pupil in the various strands (arithmetical topic). No intervention other than explaining the meaning of the print-out to the teacher was planned for the first semester. The teacher had to develop her own strategies to help the pupils with any difficulties. (It was evident that although teachers were able to understand the data contained in the print-out, they were unable to use the information to restructure their teaching strategies to cater for individual weaknesses.) Towards the end of the first semester the pupils were given a different form of the HSRC tests.

Results and discussion

Table 2 is an analysis of the pupils' performance as made by the computer after 12 and 20 sessions, together with the results of the Initial Evaluation Tests in Mathematics for the respective standards. The raw scores of the I.E.T. obtained by the pupils were converted to standard t-scores using the norm tables in the test manuals. The standard deviation for the I.E.T. t-scores is 10 and the average is 50.

The table shows us the following. The performance in mathematics of the Std 2 and 3 pupils of schools A, C, D and E in the February I.E.T. tests is very close to the national average for black pupils in these standards in South Africa. The pupils at school B performed below the national average. The performance of the Std 4 pupils at all schools was generally poorer than the national average for black pupils. The setting of an equivalent form of the same test to the same pupils in May indicated that there was, in most cases, an increase in knowledge of mathematics. Because the I.E.T. test norms are valid only for the beginning of the school year, it can be expected that after a few months' tuition, the children will have greater competence in the subject. The performance of the pupils in Std 2 and 4 of school B and the Std 3 pupils of school C did not, however, improve as expected.

Using Israeli performance criteria, the entry level of most pupils was 2 – 3 years below the expected standard. In the context of this article, the entry level relates to that attained by the pupil at the end of the introductory phase, whereas the expected level accords with the standard the pupil is in; e.g. a Std 2 pupil is at an expected level of 40 but his entry level, after 12 lessons, at the practice phase may only be 23.

The performance of the girls in the computer tests was generally better than that of the boys. After only eight lessons, the majority of pupils attained a grade placing similar to that of pupils in the next standard above them achieved during the test phase, e.g. the Std 2 girls in schools A and B attained a grading of 25 after 20 lessons, which is the same as the entry level of the Std 3 girls in schools C and D after 12 lessons. All the pupils of school B showed more or less the same improvement in their performance of basic arithmetical skills on the computer material as that of other schools. Since two standards of this school showed no improvement in their general knowledge of mathematics, as measured by the I.E.T., it would appear that the improvement in basic arithmetical skills can be ascribed to the sessions spent on the computer.

Our experience has indicated an improvement in the performance of most pupils in both types of test after eight sessions but, according to Osin (private communication), as a rule of thumb, the pupils need to be on the computer for at least 120 sessions before any great reliance can be placed on the learning gains made.

The pupils' standard of English is, in general, very low and therefore a poor performance in the word problems during the testing phase will have a significant effect on their initial grading. It is probable that the absence of any guidance of the teacher in individualized or small-group teaching methods also meant that the learning gains were not as great as they might have been.

A number of strategies are being developed to aid the teacher. For example, a manual is being compiled which will illustrate various methods of teaching mathematical concepts. The teachers will be given instruction in the use of the manual and regular class visits and meetings are already in progress. As an interim solution in Soweto, teachers are being guided in the teaching of small groups. Teachers will also attend regular sessions on the computer in order to improve their understanding of the material being presented to their pupils. An important aspect of the in-service programme that is receiving attention is the training of the teachers in the diagnosis and remediation of the pupils' difficulties in arithmetic.

They will also be asked to contribute ideas and suggestions for the drawing up of pupil worksheets to be used as part of their remedial teaching programmes. The results of the diagnostic tests will be useful in ensuring that the teachers' in-service training courses cover those areas of mathematics where pupils experience the most difficulty.

The pupils and teachers have shown great

BEST COPY AVAILABLE

enthusiasm for and cooperation in this project. Absenteeism went down on the days that the pupils attended computer sessions. Air-conditioning and carpeting of the computer room has had a profound effect upon the children and discipline is not a problem.

Conclusion

Although the project is still in its infancy, the pilot study has already shown the following: The relatively few learning gains made thus far has emphasized the need for the teacher to be totally involved in the project. Workshops to improve the teachers' own mathematical knowledge and skills in teaching arithmetic must be organized. The performance of the pupils in the HSRC tests has implied that the grading by the computer is similar to the standard expected of pupils in the various grades in South African schools. Teachers have reported that their pupils have improved their English vocabulary as a result of the word problems presented by the computer. The pupils tackle practice exercises at their own level of competence and hence do not feel threatened by peer competition. Since each individual's score is known only to the pupil, there is no embarrassment occasioned by poor performance. The teachers have made positive attempts to aid pupils with difficulties and this has resulted in some of the more able teachers attempting to give instruction to small groups. More guidance is required in this area.

Finally, although TOAM is essentially a test-and-practice system, some of the more able pupils have learnt new concepts, e.g. exponents, before the teacher has covered the work in class. This has come about as pupils are given the correct solution to an exercise after the third unsuccessful attempt. On receiving the correct answer, the more able pupils have solved similar problems.

The project is scheduled to run until December 1985.

The authors wish to thank the following: Barlow Rand for funding the project, Professor D. D. Russell for advice and guidance, the Department of Education and Training for permission to work in their schools, Mr R. C. Roos for his help, and the school principals for their cooperation.

1. Russell D. D. (1982). Applied research and development projects in formal and nonformal education — 1982. Centre for Continuing Education, University of the Witwatersrand, Johannesburg.
2. Borello E. and Italian M. (1981). Computer-based teaching in applied linguistics. In *Computers in Education*, R. Lewis and D. Tass, pp. 89 – 92. North Holland, New York.
3. de Wet J.J. and Calitz L.P. (1981). Educational needs and problems in Africa and the use of CAI. In ref. 2, pp. 563 – 7.
4. Shepherd D.H., Cooper Z.A. and Walker D.R. (1980). Computer assisted learning in geography. Council for Educational Technology, London.
5. Suppes P. and Morningstar M. (1969). Computer-assisted instruction. *Science* **166**, 343 – 350.
6. Hammond J. (1981). Computer education for the community — an Australian experiment. In ref. 2, pp. 509 – 515.
7. Osin L. (1981). Computer-assisted instruction in Israeli disadvantaged elementary schools. In ref. 2, pp. 469 – 475.
8. Roos R.C. (1981). *Manual for the Initial Evaluation Tests in Mathematics for Std 6*. Human Sciences Research Council, Pretoria.
9. Roos R.C. (1977). *Manual for the Diagnostic Tests in Mathematics*. Human Sciences Research Council, Pretoria.
10. Malan H.F.C. (1981). *Manual for the Initial Evaluation Tests in Mathematics for Std 3*. Human Sciences Research Council, Pretoria.
11. Malan H.F.C. (1980). *Manual for the Initial Evaluation Tests in Mathematics for Std 4*. Human Sciences Research Council, Pretoria.
12. Wilkinson A.C. (1981). An analysis of the problems experienced by pupils in mathematics at Standard 5 level in the developing states in the South African context. Mathematics Teacher In-service Training Project, University of Orange Free State, Bloemfontein.
13. Wilkinson A.C. (1981). Std. 5 pupils' knowledge of basic mathematical terms. A survey conducted in some developing states of Southern Africa. Mathematics Teacher In-service Training Project, UOFS, Bloemfontein.
14. Reisman F.K. (1978). *A Guide to the Diagnostic Teaching of Arithmetic*. 2nd ed. Merrill, Columbus.
15. Suppes P. and Morningstar M. (1972). *Computer Assisted Instruction at Stanford (1966 – 68)*. Academic Press, New York.
16. Macken E. and Suppes P. (1976). Evaluation studies of CCC elementary-school curriculums 1971 – 1975. *CCC Educational Studies* **1**(1).

Computer-assisted Learning in the Primary School: A South African Example

P. Waker

Primary school pupils and microcomputers suit each other well,[1] yet there has been little research on the value of the use of computers in the primary school, despite the publicity the subject has received. Two years ago, Sea Point Boys' Primary School was the first primary school in South Africa to use microcomputers for computer-assisted learning (C.A.L.). The school started with two computers, but growing demand soon led us to increase this to five.

The computers were purchased originally to assist in overcoming three of the school's most pressing problems: 1) More pupils needed remedial teaching than the school's facilities could handle. 2) The staff lacked time to provide supplementary mathematics for advanced pupils. 3) Pupils who were scholastically disadvantaged needed drill and practice facilities which were emotionally acceptable to them.

The school also considered a fourth application, administration. However, the available software did not completely cover the needs and was too expensive. The school would have saved secretarial time, but not sufficient teachers' time to justify the purchase. As suitable programs became available, however, they were purchased and implemented.

Some of the basic decisions which influenced the way computers were used in the school were: 1) The school would rely on purchased programs and adapt these to local circumstances. 2) The program must require a minimum of teacher assistance, otherwise it could defeat the object of the exercise. 3) Computer time for pupils would be scheduled to suit the teacher; rather have inefficient use of the computer than inefficient use of the teacher. (The teacher remains the most effective and most expensive aid to learning.)

During the past two years, the uses we have put to computers have developed in many directions, including administration, but the above three principles have remained paramount. Only recently has the school developed its first in-house program, to teach Afrikaans as a second language.

Spelling

Of the pupils needing some remedial help, the largest group was those with spelling problems. Although the school follows a spelling programme which has lifted the school average well above the national average, a large number of pupils fared badly in spelling compared to other subjects. We compared the scores of standardised Human Sciences Research Council spelling tests with the following: 1) general ability (HSRC IQ tests); 2) ability in English (HSRC Scholastic tests); 3) school marks. If spelling was lower by at least 20 percentile rankings in each of these comparisons, the pupil was regarded as requiring help with spelling. A total of 41 pupils in Standards 2, 3, 4 and 5 were identified as needing remedial spelling. The method is rather crude in that it does not help to identify underlying causes, and can therefore lead to true remediation only by chance. Where the scholastic history of the pupils was known, it

The author is headmaster of Sea Point Boys' Primary School, 175 High Level Road, Sea Point 8001, South Africa.

BEST COPY AVAILABLE

was evident that their teachers had relied heavily on 'phonic' methods to teach spelling. Only a few parents and pupils reported reliably that teachers had, on a very limited scale, used alternative approaches, such as looking at the word and writing it 'in the air', or by the 'look-cover-write-check' procedure.

Lacking both the time and the expertise to develop its own software, the school purchased American spelling programs. The most suitable of these was the Compu-Spell set from Edu-Ware of California. A short trial run confirmed that the pupils were learning from the programs and could operate them without teacher assistance. The programs were then modified extensively; especially to eradicate American spelling and to adapt the content to match the experience of South African pupils.

When the pupil logs in at the computer, he is presented with his particular lesson of ten related spelling words in appropriate sentences. There are 70 such lessons for each of the Standards 2, 3, 4 and 5. The program will take the pupil through each lesson twice. During the learning run the computer gives a clue as to the length of the word, as well as a clue presented by the sentence. Only correct responses are accepted, thus ensuring a favourable 'pain to gain' ratio.[2]

The program then tests the spelling before the pupil is given the choice of logging off or going on to the next lesson. Originally, the program insisted on a 100% correct answer before allowing the pupil to proceed to the next lesson, but it was found necessary to reduce this to 80% to allow for typing errors. Words which presented problems to the pupil are repeated both immediately after each lesson and in subsequent lessons until completely mastered. The program includes a management mode which allows the teacher to check the progress of all pupils. At Sea Point teachers and the principal were given weekly print-outs reporting on the progress of each pupil.

Pupils in groups of six were introduced to the program by means of a demonstration lasting ten to fifteen minutes. Thereafter, teacher intervention was limited to approximately 30 minutes per week for the entire group. Most of this time was spent loading disks, making back-up copies and printing reports for the teachers. The intention was that teachers would look for patterns in the 'trouble words' and explain the relevant spelling rules to the pupil concerned. This hardly ever happened in practice. Pupils' mistakes showed no pattern and were probably only typing errors. Additionally, they seemed to resent intrusion by the teacher in the relationship between learner and computer.

The program offered an alternative way of learning to spell. Instead of stressing phonics, it emphasized visual memory and sequential memory. Even though no method of preselecting those who would respond to this mode of learning was available, the 35 pupils left in the test group progressed at more than double the rate of the rest of the pupils during the six months of controlled experiment (13.5 months progress for the test group in contrast to 6.4 months for the control group). As the spelling words in the subsequent test were not the same as those that had been taught, it seems that pupils do transfer the spelling skills acquired to other words.

However, that is not the whole story. It was reported by one parent and confirmed by a few pupils that some boys in the test group had deliberately under-achieved in the later test in order to remain in the remedial spelling group. A check revealed very few cases of blatant under-achieving. We suspect that some other pupils may have been sophisticated enough not to make their under-achieving obvious. This little bit of sabotage illustrates what an extremely powerful motivator the computer is when the machines are in short supply. Teachers noticed that pupils were doing more spelling units per week after six months than after the first month, despite the rather boring nature of the spelling program.

The school is at present developing a version of the spelling program to be used for the teaching of the second language (Afrikaans in this case).

Enrichment

A group of 30 Std 3, 4, and 5 pupils were selected by their teachers, according to their apparent need for and ability to cope with an additional challenge. Seventeen simulation programs, such as Hamurabi and Lemonade, were purchased. After an introduction to the computer, and a few demonstrations on how to load disks and run programs, the pupils were left to operate the computer without much further assistance. Each pupil had a diary containing worksheets which helped to keep track of the programs used, times and scores.

Because of a lack of suitable programs, the experiment was completed in the relatively short time of four months. During this time the enrichment group made more progress in their ability to find and estimate answers for quantitative problems than the rest of the pupils, but the difference was not statistically significant (6 months vs. 5.5 months). It is possible that here, too, there were cases where pupils deliberately underachieved in order to remain in the computer group. Most progress seems to have been made by those pupils who interested themselves in learning BASIC.

It has long been suspected that learning a computer language leads to better problem solving skills, but confirming such a belief has been difficult. Although Morse claims superior problem solving skills for Computer Study pupils,[3] researchers involved in the Edinburgh and the Brooklyn Logo projects, working with primary school children, were unable to prove significant gains in mathematical problem solving as a result of exposure to Logo.[4]

Like the Logo researchers, Sea Point Boys' Primary staff considered the existing tests were not evaluating what they hoped the computer was teaching. A new test of 50 graded problems involving quantitative decisions and manipulations was devised. Many of the test items bear a close resemblance to IQ questions. Tests drawn up by other researchers such as Morse also bear a resemblance to IQ tests. This leaves us with the question: were we trying to prove that learning and using computer languages at a school-going age improves intelligence?

Some C.A.L. practitioners are moving away from quantitative methods of research altogether, on the grounds that they are insufficient to evaluate techniques which not only bring a new way of learning, but also ways of learning new things.[5] From conversations with pupils and recordings of their conversations with each other, it seems that they do not develop strategies involving algorithms to maximise the results in a simulation, but rather work by trial and error, often establishing two extreme values and then finding the optimum by moving in step by step from both sides. Had suitable simulations and games been available, it would have been better to use the computer to support the class teaching or, alternatively, use the class teaching to support the computer programs.[6]

Sea Point Boys' Primary had all its software and most of its hardware stolen during a recent burglary, but as soon as this has been replaced, we will be investigating, among other things: 1) The influence of word-processing on children's writing; 2) Logo, and its influence on the mathematical ability and problem solving skills of South African pupils; 3) second language teaching, using the program and strategies evolved for remedial spelling. In addition, progress with spelling, subject enrichment and scholastically disadvantaged pupils will be monitored.

1. Waker P. (1982). Computer assisted learning in the primary school: now and in the near future. *Proc. SACCE 82*, pp. 525 – 533, University of Stellenbosch.
2. Burke R.L. (1982). *CAI Sourcebook*, p. 30, Prentice Hall, New Jersey.
3. Morse J. (1981). Problem solving, programming and computer studies. *Classroom Computing* **1**, 30 – 36.
4. Watt D. (1981). Logo in the schools. *Byte* August, 116 – 134.
5. Rushby M. (1981). In *Selected Reading in Computer-Based Learning*, edit. M. Rushby, chap. 1, pp. 13 – 29. Kogan Page, London.
6. Hartley J.R. (1978). In ref. 5, chap. 2, pp. 30 – 43.

BEST COPY AVAILABLE

Microcomputers, Conceptual Change and the Design of Science Instruction: Examples from Kinematics and Dynamics

Peter W. Hewson

The microcomputer has arrived on the educational scene. The combination of low cost and versatility has meant that its appeal is eclectic — administrators, teachers and students can all justify the modest outlay for a variety of reasons, ranging from the serious to the trivial. There is every reason to expect that within a few short years, the microcomputer will be as ubiquitous in schools as overhead, slide and movie projectors.

But what will be its impact in the long term? Will cost-conscious accountants find that books are able to supply students with the same information at a fraction of the cost, and without the possibility of being diverted into mindless arcade game playing? Or will education take on the magical quality of George Leonard's vision in *Education and Ecstacy*?[1] In my view, this depends on the ingenuity with which we explore the possibilities in the new medium. On the one hand, using the microcomputer to take over the functions that older technologies and techniques have performed satisfactorily will be a self-defeating exercise. On the other hand, finding new functions which could not be performed in the past holds the potential of opening vistas in the future which are unimagined in the present.

In this article, I shall be exploring one possible function for the microcomputer in education. This new function arises from the constructivist view of learning which I recently discussed in this journal;[2] it is a view which explains the now well-documented finding that all students bring to the science classroom surprisingly extensive theories about how the natural world works.[3,4] As Champagne, Klopfer and Gunstone[5] have pointed out, these theories (which they call 'alternative conceptual systems', Driver[6] calls 'alternative frameworks', and which I shall refer to as 'alternative conceptions'[7]) have some interesting characteristics:

- they are often held by students who have had no formal instruction in the subject;
- they are often significantly different from generally accepted views of the subject;
- they are consistent across different groups; and
- they are surprisingly resistant to change as a result of traditional instruction.

More specifically, I shall be considering if a microcomputer can be used to diagnose whether a student holds a specific alternative conception and, if so, to provide remedial instruction based on a model of learning as conceptual change which will assist the student to change his or her views.

In the rest of this article I shall:

- discuss current usage of microcomputers in science instruction;
- review the relevant literature on alternative conceptions, with particular attention to the concepts of speed and force;
- outline a theory of conceptual change which suggests how to design instruction aimed at replacing alternative conceptions;
- describe microcomputer programs designed to diagnose and remediate some alternative conceptions of speed and force;
- outline the results of using these programs with first year university students; and
- summarize the outcomes of the paper.

Microcomputers in science instruction

Microcomputers have a number of considerable advantages over many of the other educational media presently in use.[8] Firstly, students can interact directly with a microcomputer. Thus, provided the software requires it of them, students play a very much more active role in learning than with other media. Secondly, students can get individual attention for their specific difficulties from the microcomputer. Thirdly, microcomputers allow students to control the pace at which they work, so that a student who is having difficulty with one particular section of work can take the time needed to master it before moving on to the next section.

Microcomputers are currently being used in a number of different ways in science instruction at both secondary and tertiary levels,[9] all of which make at least some use of their specific capabilities.

Numerical work

The ability of the microcomputer to perform numerical calculations rapidly and efficiently allows students to investigate the scientific rather than the mathematical aspects of equations by eliminating tedious calculation. For example, introductory physics courses are generally restricted to those problems for which the laws of motion can be solved analytically. This restriction can now be removed, since iterative solution techniques are easy to implement on a computer.

Drill and testing

The capability of storing many questions in a data bank, of varying the type and content of questions asked, of asking many different questions in a relatively short period of time, of recording and evaluating student responses, of being able to give feedback based on the student's response and of being readily available, makes drill and testing obvious functions of a microcomputer in science instruction

Tutorial

The microcomputer cannot compete with a book purely in the presentation of information. When its interactive capability is, however, combined with the presentation of information, programs with carefully designed questions and branches which allow a student to take different paths through the material, can involve him or her far more actively in learning than a book can. This advantage is particularly enhanced when dynamic graphics are used.

Simulation

All too frequently, real world experiences are difficult to repeat in the laboratory, are too complicated for introductory students to analyse, happen too rapidly to be seen, can only be observed using complicated instrumentation which obscures the desired phenomena, or are otherwise unexaminable. The ability of the microcomputer to simulate this type of phenomenon allows the student to expand his or her range of experiences greatly.

Real time use

Scientists have interfaced computers with their experimental apparatus for years. Thompson, however, points out that this capability can bring experiments which are normally unavailable into the student laboratory.

As Bork points out, the microcomputer's capability of individual response means that

The author is in the Department of Physics, University of the Witwatersrand, Johannesburg 2001, South Africa.

BEST COPY AVAILABLE

it can play the role of a Socratic tutor, by leading the student through a series of carefully structured questions which are responsive to his or her answers.

These are exciting possibilities but as Bork indicates, they represent the state of the art, rather than a final definitive list. There are likely to be far-reaching consequences for courses, curricula and institutions as a result of current and future developments in both computer hardware and software. There is much to be learned about how people learn and about how to incorporate this into the design of instructional software.

Alternative conceptions

As I have outlined elsewhere,[10] the occurrence of alternative conceptions is consistent with two other ideas which are of particular importance in science education today. Firstly, people strive to make sense of their experience. Secondly, people use the knowledge they possess in their attempts to make sense of their experience. Thus, as a direct result of the above two ideas, individuals from different backgrounds, having different experiences and knowing different things, are likely to construct alternative conceptions from the same information.

The significance of alternative conceptions depends, among other things, on the large number of different alternatives in different content areas which have been identified to date, the considerable number of students who hold them, and, more tentatively, the suggestion that environmental, linguistic and cultural factors play a part in their occurrence. Researchers from various countries have documented alternative conceptions in topics as diverse as vectors, kinematics, dynamics (including friction, gravity, energy, momentum and pressure), heat and temperature, electricity, light, density (including mass and volume), the particulate theory of matter, the earth as a cosmic body, evolution, heredity, the circulatory system and life. For example dynamics and kinematics have been reviewed by McDermott,[11] and heat, temperature, light and electricity by Tiberghien.[12] A more extensive, but less detailed, review has been provided by Driver and Erickson.[13]

At a recent international seminar on 'Misconceptions in Science and Mathematics', more than 50 papers were presented on topics in physics, chemistry, biology and mathematics.[3] The interest engendered by the seminar, which attracted participants from many countries, and the extent of the list given above are just two indications that alternative conceptions are a factor which can no longer be ignored in science education today.

An alternative conception of speed

The alternative conception of speed considered in this article was first identified by Trowbridge and McDermott[14] in the course of a systematic study of the ways in which students think about motion. By using apparatus which allowed them to demonstrate the same motion repeatedly, they assessed understanding of students' conceptions of speed by the degree to which a student successfully applied this conception to the interpretation of these simple motions of real objects. More specifically, they found that, before instruction, at least 30% of all students enrolled in a wide variety of introductory physics courses at the University of Washington were unable to compare the speeds of two objects satisfactorily. In general, these students used a 'position' criterion for determining when two objects were moving at the same speed. In other words, when two objects were next to one another (i.e. at the same position), the students said that they were moving at the same speed. Conversely, they also concluded that when two objects maintained a constant separation, they were not moving at the same speed. A possible reason for the plausibility of this conception arises from the fact that sometimes, such as when two cars travel next to one another on the freeway, the position criterion will give the right answer. In other cases, such as when one car overtakes a second, it does not. One of the microcomputer programs described below was designed to address this alternative conception of speed.

Alternative conceptions of force

Research into alternative conceptions of force has shown that they form a complex of interlocking ideas which are far more extended and pervasive than is the case with the alternative conception of speed considered above. For example, Watts[15] outlined eight distinctive alternative conceptions of force. In order to keep the number of programs to manageable proportions in the first instance, it was necessary to consider only those alternatives which were most prevalent and therefore most likely to cause difficulty in first year physics.

The major alternative conception which was considered is centred on the concept of force in the context of a consideration of motion and its causes. The essence of this conception is that a force is necessary whenever motion is present. Viennot[16] found that a student holding this conception would use the velocity of an object, rather than its acceleration, to deduce the presence of forces. Her results indicated that the use of this conception was dependent on the context of the question which was asked. If the total motion of the object was given, its use was far more prevalent than if students were given an equation of motion and asked to calculate the force. She called this the 'supply of force' notion, i.e. 'the force in a body which keeps it moving'. Clement[17] summarized the same idea as 'motion implies a force', noted that this 'force' was more likely to be used when there was an obvious opposing force, and that students thought it would 'die out' or 'build up' in order to account for changes in speed. Watts drew a distinction between a conception in which the motion itself is the force, typically expressed as 'the force of the moving object'; and one in which the force is external to the moving object, but without being identified with any other object. He has paraphrased this latter notion as follows: 'If a body is moving there is a force acting upon it in the direction of the movement. If a body is not moving there is no force acting upon it.'

Another aspect of the alternative conception of 'motion implies a force', about which Viennot, Clement and Watts have all agreed, is the frequent lack of a distinction between force and energy. For example, Viennot commented that energy in many situations 'is inextricably mixed with the concept of force in a single undifferentiated complex', and Watts claimed that for some students force is energy.

Motion is of interest because many students regard it as a force, but in the Newtonian sense it is not. In contrast, the reverse is the case with two other concepts — gravity and friction. Many students do not regard them as forces, although in the Newtonian sense they are. Although there has been some research into this question,[18-20] the reasons for this are speculative. It seems, however, that some students tend to think of forces as associated with active agents such as people or machines.[21] The corollary to this is that they find it hard to conceive of passive agents exerting a force, such as a table exerting a force on the book which it is supporting. Gravity and friction are likewise not regarded as forces because they are due to passive agents. This is most clearly shown by students who feel there is no need to provide any explanation of why objects fall to the ground, or why moving objects slow down as they move across a surface — they regard them as natural occurrences.

A model of conceptual change

In this study the question of how a microcomputer can make explicit use of an identified alternative conception in remedial instruction was addressed by thinking of learning as a change in a student's conception. From this point of view, learning involves an interaction between new and existing conceptions with the outcome being dependent on the nature of the interaction. If these conceptions can be reconciled, learning proceeds without problem. If, however, they cannot be reconciled, then learning requires that existing conceptions be restructured or even exchanged for the new. The recognition that change of this nature may have to occur forms the basis of

BEST COPY AVAILABLE

the model of learning as conceptual change which we have developed.[10 22]

The model of conceptual change outlines the conditions which a new conception has to satisfy before it can be integrated with existing knowledge. Three questions must be asked of each conception:

- Is it intelligible (*I*)? Does the person know what it means? Can he or she construct a coherent representation of it and see that it is internally consistent, without necessarily believing it to be true?
- Is it plausible (*P*)? In addition to being intelligible, is it also true? Is it reconcilable with other existing conceptions? Is it how the world really is?
- Is it fruitful (*F*)? In addition to being plausible, is it useful? Does it clear up anomalous results? Does it suggest further experiments or new approaches?

The answers to these three questions are used to determine the status of a question — no status if all three answers are negative; status *I* if the first answer is positive; status *IP* if the first two answers are positive; and status *IPF* if all three answers are positive. Because conceptual change can occur only when status changes, the next question to consider is: how does status change? It does not change spontaneously. It is lowered only if there is cause for dissatisfaction, and it rises only if sources of dissatisfaction are removed and some advantage is gained. In other words, the success of a microcomputer program designed to effect conceptual change depends, in part, on the extent to which it is able to make a student dissatisfied with the conceptions which he or she holds.

Effecting conceptual change with

The implications of the conceptual change model for addressing alternative conceptions are straightforward. These are:

1) Diagnosis. It is necessary to know whether or not any given student holds the alternative conception under consideration. This can be determined only by using a diagnostic test.

2) Remediation — the lowering of status. The model indicates that it is reasonable to assume that a student holding a conception does so because its status is at least *IP*. If, however, this conception is irreconcilable with a new conception which is to be taught, then it is impossible for the status of the new conception to rise to *IP* until the status of the existing conception falls. In other words, it is necessary to address the old conception with the explicit intention of creating dissatisfaction with it, thereby lowering its status.

3) Remediation — the raising of status. Teachers have always put considerable effort into explaining new ideas. In terms of the model, this will always be necessary in order to make a new idea intelligible to the student. In addition, however, the model suggests that it is necessary to show that the new conception is a better option than the old, because it does what the old could not do and more. In other words, it is necessary to raise the status of the new to *IPF*, or at least *IP*.

The ability of the microcomputer to allow a student to interact actively with instructional material and to follow an individualized path at his or her own pace is very useful in designing instruction to achieve the three stages outlined above. For example, the results of the diagnostic test will show whether the student holds an alternative conception whose status needs to be lowered. On this basis, the student can be directed to specific remedial programs which can be worked through as and when required. In addition, the ability of the microcomputer to simulate motion is particularly useful in the work described in this article, because of the central role which motion plays in the alternative conceptions of speed and force which I outlined above.

A microcomputer program on speed

The program was designed to diagnose students who used a position criterion for comparing relative motion, and to provide remedial sequences whose aim was to persuade these students to change to an acceptable criterion. It is clear that this is a relatively unimportant alternative conception which is simple to identify and relatively isolated from other alternatives, and which many students correct for themselves. It was, however, chosen for the following reasons. Firstly, the position criterion seems to be the only plausible alternative. Trowbridge and McDermott[14] comment that 'virtually every failure to make a proper comparison can be attributed to use of the position criterion to determine relative velocity'. This makes the remedial task significantly easier. Secondly, if we are able to diagnose and remedy a simple example such as this using a microcomputer, it ought to provide us with guidelines for tackling alternatives which are more significant and more complex.

Diagnosis

The diagnostic stage consists of six different races in each of which two 'cars' move from left to right across the screen. The student records a response by pressing a control button in accord with the instruction: 'Press the button when you think the two cars are moving at the same speed.'

The races, which include the two used by Trowbridge and McDermott, were designed on the basis of their ability to distinguish between the correct and position criteria. In other words, there are no occasions where both cars are moving side by side at the same speed. In addition, other factors such as acceleration and deceleration, which affect the perceptual appearance of the races without changing the essential components of the task, are varied. The use of six races is necessary to allow for possible mistakes and to provide a greater assurance that the diagnosis made is the correct one.

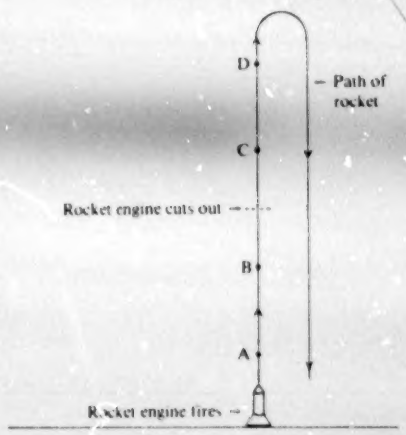


Fig. 1. Summary of task set by first diagnostic program (DG 1): What forces (names, directions, comparative magnitudes) are acting on the rocket at points *A*, *B*, *C* and *D*?

Remediation

In the program the two aspects of the remedial stage are combined in two further races which were designed to lower the status of the position criterion while at the same time introducing the correct criterion. This was done by considering two extreme cases which introduce perceptual anomalies for a student using the position criterion. In the first case, one car remains in the centre of the screen, clearly not moving; while the other travels past it at a constant speed, equally obviously in motion. The race clearly pinpoints the anomaly by showing one car moving and the other stationary while at the same point. In the second case, both cars travel at the same constant speed across the screen, with the distance between them remaining constant, i.e. they do not pass one another. This race shows that two cars do not have to be at the same place while moving with the same speed, and at the same time introduces the correct criterion of the constant inter-car distance.

Results of program use

It is possible for a student in one session of 20 minutes to work through the diagnosis part of the program and, if necessary, to do the remedial work and repeat the diagnosis. It is easy, therefore, to gather data on the effect of the program itself, as opposed to other possible influences on student responses. The responses obtained from 85 students in a first year physics course at this university [Physics I(J1)] are representative of the results which the program can achieve. A total of 23 students could not judge speeds correctly. Of these, 14 worked

BEST COPY AVAILABLE

Table 1. Correct (C), 'position' (P)' and random (X) scores of 7 Physics I(J1) students in February 1983.

	CPX score		Change in scores		
Student	Before	After	ΔC	ΔP	ΔX
A	060	403	+4	−6	+3
B	431	502	+1	−3	+1
C	264	222	0	+2	−2
D	251	433	+2	−2	+2
E	241	500	+3	−4	−1
F	240	600	+4	−4	0
G	214	501	+3	−1	−3

through the remedial part and repeated the diagnosis, and 10 out of 14 changed and were able to judge speeds correctly. Even without a full-scale evaluation, it is possible to see that the program is doing very satisfactorily what it was designed to do.

It is necessary in interpreting the results of students who did not respond correctly to note that the data is gathered in the form of correct (C), position (P) and random (X) responses to the six diagnostic races. Because it is possible to make more than one type of response to a given race, the total number of responses may be more than six. The C, P and X scores of a representative group of these students before and after doing the remedial program are shown in Table 1, together with the changes in these scores.

It is clear that there was a substantial increase in the number of C scores, and a corresponding decrease in P scores, with some of the individual changes being particularly striking. The significance of these changes is strengthened by considering that students were not shown which were the correct points in the diagnostic races, but were simply shown the procedure which they had to apply for themselves. In addition the same students were asked a few weeks later about their responses. Those whose responses had not changed immediately after the program were still confused. One response here was that cars would move at the same speed 'when their speeds remain constant, and when they travelled together (side by side)'. Conversely, those who had changed, acknowledged their change, and could explain how they now judged equal speeds. For example, one student said he 'made a mistake the first time by taking the point where they pass each other as the same speed' and would now look for 'when they keep more or less the same distance apart'.

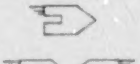
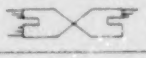
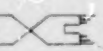
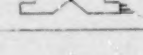
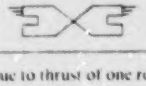
Microcomputer programs on force

The programs were designed for students who believe that moving objects always require forces to keep them moving, who confuse force with related concepts such as energy and momentum, and who think that forces are due to active agents and are therefore uncertain about gravity and friction. In order to address these ideas, it is necessary to be able to discuss a prototypical force about which there is likely to be general agreement. The most common prototypes are probably human pushes or pulls, but they suffer from the problem that they are generally variable in magnitude and of short duration. The force exerted by a rocket, however, is clearly an active force, and it is easy to imagine how to control the magnitude, the direction and the duration of the force. As a result the rocket is a constant theme throughout the programs.

Diagnosis

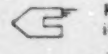
The diagnostic programs were adapted from a task used by Clement,[17] in which he asked students to consider the forces which acted on a coin that was thrown vertically upwards. More specifically, he asked them to name the forces, to show their directions and to compare their magnitudes after the coin had left the hand, and while it was still moving upwards. Clement found that this task evoked the response that there was an upward force from 70% of a group of engineering students who had completed a first course of university physics. On a similar task, 33% of the first year physics major students at this university gave the same response after completing the section on mechanics. In other words, it is a good task for identifying students who hold the alternative conception that 'motion implies a force'.

The first diagnostic task (DG 1) simulates the motion of a rocket which takes off vertically upwards. After a short while, the engine cuts out and the rocket continues to

Type of motion	Examples considered	Newtonian explanation
speeding up v (−) a (−)		RT (−) = FR (−)
		2RT (−) + RT (−) = FR (−)
slowing down v (−) a (+)		RT (−) = FR (−)
		RT (−) + 2RT (−) = FR (−)
constant velocity v (−) a = 0		FR = 0
		RT (−) + RT (−) = 0

RT — force due to thrust of one rocket engine
FR — resultant force on rocket

Fig. 2. The Newtonian explanation of three types of motion considered in first remedial program (RM 1). All rockets move from left to right. Arrows in brackets show directions only, and not magnitudes.

Type of motion	Examples considered	'Motion force' explanation
Constant velocity v (−) a = 0	engine off 	MF (−) MF increases with v
speeding up v (−) a (−)		RT (−) possibly MF (−) ∴ FR (−)
slowing down v (−) a (−)		RT (−); MF (−) if v large enough, MF > RT ∴ FR (−)

MF — 'motion force' of rocket
RT — force due to thrust of one rocket engine
FR — resultant force on rocket

Fig. 3. The 'motion force' explanation of three types of motion considered in second remedial program (RM 2). All rockets move from left to right. Arrows in brackets show directions only, and not magnitudes.

BEST COPY AVAILABLE

move upwards but now slows down until it stops, before falling back to earth. Students are asked to consider the forces acting on the rocket at four points — after take-off, before and after engine cut-out, and before the rocket stops moving upwards. At each point they are asked to name the forces acting, give their directions and compare their magnitudes. In addition they are asked whether the same forces are acting at successive points, and if so, how their magnitudes compare. The task is summarized in Fig. 1.

This task was designed to answer the following questions: What types of quantities are regarded as forces? In particular, does the student regard gravity and motion as forces? With respect to magnitudes, is the largest force necessarily in the direction of motion?

The second diagnostic task (DG 2) simulates the motion of a rocket travelling horizontally on a track which can be either rough or smooth, i.e. frictionless. The rocket starts from rest, speeds up until the engine cuts out, and then either slows down (Part I) or continues moving at a constant speed (Part II), depending on whether or not the track is smooth. In a further option on the smooth surface, the engine does not cut out, but instead reverses its direction so that the rocket slows down, stops, and moves off in the opposite direction. As before, the students are asked to name the forces, give their directions and compare their magnitudes at different points while the engine is on and after cut-out or direction reversal. This task was designed to gather the additional information of whether students regarded friction as a force and how they related forces to a constant velocity motion.

Remediation

The remedial programs use Viennot's result that the force conception which a student uses depends on the context in which the task is set. In other words, there are examples where there is general agreement that a prototypical force is acting. The overall aim of the remedial programs is to establish what effect such a prototypical force, or combination of such forces, has on the motion of an object. Once these effects are established, the argument is turned around and they are used to determine what forces might be acting on an object whose motion is given. Included in these motions are those which give rise to the alternative conceptions discussed above, so that the conflicting explanations can be compared.

The first remedial program (RM 1) was designed to establish the effect that prototypical forces have on the motion of an object on which they act. For the reasons discussed above, rocket engines were used to exert prototypical forces, and for simplicity motion was restricted to one dimension. By using combinations of simple constant-thrust rockets which can be either on or off, or act to the left or the right, different resultant forces can be obtained. Within these constraints, the effects of forces can be determined in qualitative terms, i.e. a force acting on its own, or the resultant of a number of forces, is able to accelerate (speed up) an object which is either at rest or already moving; and is able to decelerate (slow down), stop and change the direction of a moving object. As important as these effects is the converse: when no force or a zero resultant force acts on a moving object, the object continues to move with an unchanging velocity. These results are summarized in Fig. 2.

The second remedial program (RM 2) was designed to address the alternative conception of 'motion implies a force'. Some characteristics of such a 'motion force' are first established using an example particularly likely to evoke this conception: an object moving with constant velocity without any obvious force in the direction of motion. In particular, the idea is established that if the 'motion force' exists, it is reasonable to expect it to increase with the speed of the object. After considering the uncontroversial example of an object which is speeding up, the crucial example is presented. An object is shown to be slowing down under the action of a rocket firing in the reverse direction to that of the 'motion force'. The direction of the resultant of rocket force and motion force depends on their relative magnitudes, and since by considering an object which is moving fast enough, it is always possible to have a motion force larger than the rocket force, there must be a case where the 'resultant' is in the direction of motion, while the object is slowing down. These results, based on the same three examples used in RM 1, are summarized in Fig. 3.

The last result, however, contradicts what happens when only prototypical forces act; i.e. it is designed to lower the status of the 'motion force' conception. The process is carried on by showing that a 'motion force' on its own is unable to have the same effect as a prototypical force; i.e. to change velocity, and finally the fact that a moving object is different from a stationary object is recognized by differentiating the force itself from the motion produced, and calling the latter momentum rather than motion force.

The third remedial program (RM 3) was designed to address the alternative conception that passive agents, such as gravity and friction, were not forces. By using similar examples, and allowing the student to experiment with motions in which gravity and friction could be switched on or off at will, he or she was shown that these two could be regarded as forces, because they were able to produce the same effects that prototypical forces did.

Results of program use

The responses made by students who have used these programs have provided answers to many of the questions posed above. These answers are, however, tentative and at this stage specific to Physics I(J1) because trial versions of the programs were used, and they need to be revised. In addition, the second diagnostic program (DG 2) was available only well after the mechanics section of the course had been taught. Thus, because a considerable amount of time intervened between the use of different programs, it is impossible to attribute any specific effect to them.

What types of quantities do Physics I(J1) students regard as forces? This can be determined from the diagnostic programs which require students to type in the names of forces acting. Within the context of the rocket tasks, the responses to DG 1 in February 1983 show five main types of force, only three of these being Newtonian. These three were gravitational force, frictional forces (e.g. 'friction', 'air resistance', 'drag') and rocket thrust (e.g. 'propulsion', 'engine'). Both of the other types were closely related to Viennot's 'supply of force' and Clement's 'motion implies a force' notion. On the one hand was the idea that the property which the rocket had because of its motion was a force. 'Motion', 'momentum', 'inertia', 'inner force', 'kinetic energy' were examples in this category. On the other hand, terms were used which were more descriptive of the motion; e.g. 'speed', 'terminal', 'acceleration', 'upward'. In August 1983, the same categories of response were made to DG 2, although as is shown later, the frequency of the non-Newtonian categories was much lower. These changes are consistent with responses to a question asked in DG 2, 'Are there quantities other than forces which affect the motion of a rocket?' A significant number of students listed 'momentum' or 'inertia'.

A number of more specific questions, all of which require yes/no answers, are given in Table 2. The number of students whose responses enabled an answer to be given is listed, together with the percentage of the group who gave a 'yes' answer.

The responses to questions 1 and 2 show that Physics I(J1) students have little difficulty in identifying the 'passive' quantities of gravity and friction as forces. This confirms the pattern of responses to the more general question discussed above.

Question 3: Is motion a force? This idea is much more prevalent, with more than 60% of the class concurring at the start of the year. As the year progressed, with students working through the remedial programs and attending course lectures on the topic, this percentage dropped significantly to 20%. While this is still not satisfactory, the fact that the responses were made to a range of

BEST COPY AVAILABLE

Table 2. Student responses to various questions on dynamics; in percentage of available group agreeing and disagreeing with question.

Question	Yes (%)	No (%)	Group size	Source	Date
1. Is gravity a force?	88	12	127	DG 1	2/83
2. Is friction a force?	95	5	79	DG 2(I)	8/83
3. Is motion a force?					
(i) $v\uparrow; a\downarrow$.	63	37	76	DG 1	2/83
(ii) $v-; a\downarrow$.	39	61	122	Class test	3/83
(iii) $v-; a-$.	24	76	70	DG 2(I)	8/83
(iv) $v-; a = 0$.	27	73	75	DG 2(II)	8/83
4. Does thrust increase with speed					
(i) when gravity opposes motion?	54	46	76	DG 1	2/83
(ii) when friction opposes motion?	68	32	66	DG 2(I)	8/83
(iii) when no force opposes motion?	53	47	73	DG 2(II)	8/83
5. Is larger force in dirn. of motion?					
(i) $v\uparrow; a\downarrow$.	82	18	28	DG 1	2/83
(ii) $v-; a-$.	43	57	21	DG 2(I)	8/83

different tasks, both pencil-and-paper and computer-based, suggests that a genuine change has occurred. This, however, needs to be considered in relation to the next question.

Question 4: Does rocket thrust increase with speed? This is a clear expectation of the 'motion implies a force' view, whereas it is not a crucial question for Newtonian mechanics in which increasing, constant and decreasing rocket forces can all produce a speed increase. The diagnostic programs clearly stated, however, that the rocket exerted a constant thrust, so the fact that more than 50% of the available groups of Physics I(J1) students consistently responded affirmatively to the question indicates that the lower percentage of students who state that motion is a force must be regarded circumspectly. Of relevance are the following points. Firstly, question 3 was addressed explicitly in remedial programs whereas Question 4 was not. Secondly, the context-dependency of students' answers is shown by the larger percentage who thought that rocket thrust increased with speed when friction was present. Finally, 8 out of 10 students who changed their responses when friction was present did not think that motion was a force. In other words, the relationship between responses to Questions 3 and 4 is not obvious and needs further consideration.

Question 5: Is the larger force in the direction of motion? Reponses to this question could be given only by students who had already shown that they required a 'force' in the direction of motion. Amongst this group, there was a substantial drop in affirmative answers. This may be a response to the second remedial program (RM 2), which was designed to identify the contradiction inherent in the 'motion force' being the largest on a rocket which is slowing down. This, therefore, is also a result which requires more investigation.

Summary

In this article, I have described the use of microcomputers in addressing students' alternative conceptions of physical phenomena by means of diagnostic and remedial programs. The programs have been designed in accord with a model of conceptual change which implies that instruction should involve the identification or diagnosis of students' conceptions and the lowering of the status or remediation of these conceptions where they are alternative to what is to be taught, in addition to the raising of the status of the new content being taught.

The programs were designed to diagnose and remediate alternative conceptions of speed and force. With respect to speed the results show that this alternative conception is held by many students at first year university level, and that the remedial program is able to effect dramatic changes to this alternative conception. With respect to force, the results show that the programs were able to diagnose a number of interrelated aspects of alternative conceptions of force. Although there is some evidence that student conceptions changed during the course of the year, it is not yet possible to attribute this to the remedial programs, both because of their preliminary nature and because of the complexity of the notion of force in relation to the wide range of situations in which it is applicable. In conclusion, I believe that the research reported in this article is important because it provides a valuable addition to the current range of instructional applications of microcomputers, and it demonstrates the value of the conceptual change model of learning in the design of computer-aided instruction.

I wish to thank P. Dawson, E. Hallendorff and W. Sinclair for assistance in the development and use of the programs; and the Richard Ward Endowment Fund and the Human Sciences Research Council for financial support.

1. Leonard G.B. (1968). *Education and Ecstacy*. Dell, New York.
2. Hewson P.W. (1980). Learning and teaching science. *S. Afr. J. Sci.* **76**, 397 – 403.
3. Resnick L.B. (1983). Mathematics and science learning: a new conception. *Science* **220**, 477 – 478.
4. Helm H. and Novak J.D. (eds) (1983). *Misconceptions in Science and Mathematics*. Department of Education, Cornell University, Ithaca.
5. Champagne A.B., Klopfer L.E. and Gunstone R.F. (1982). Cognitive research and the design of science instruction. *Educ. Psychol.* **17**, 31 – 53.
6. Driver R. (1981). Pupil's alternative frameworks in science. *Eur. J. Sci. Educ.* **3**, 93 – 101.
7. Hewson M.G. (1982). *Students' existing knowledge as a factor influencing the acquisition of scientific knowledge*. PhD thesis, University of the Witwatersrand, Johannesburg.
8. Bork A. (1981). Computer-based instruction in physics. *Physics Today* **34**, 24 – 30.
9. Thompson D.L. (1982). *Microcomputers and School Physics*. Pitman, London.
10. Hewson P.W. (1981). A conceptual change approach to learning science. *Eur. J. Sci. Educ.* **3**, 383 – 396.
11. McDermott L.C. (1983). Critical review of research concerning students' understanding of kinematics and dynamics. Invited lecture, *International Workshop on Physics Education*, La Londe les Maures, France.
12. Tiberghien A. (1983). Critical review of research concerning students' understanding of temperature, heat and electric circuits. Invited lecture, *International Workshop on Physics Education*, La Londe les Maures, France.
13. Driver R. and Erickson G. (1983). Theories-in-action: some theoretical and empirical issues in the study of students' conceptual frameworks in science. *Stud. Sci. Educ.* **10**,.
14. Trowbridge D.E. and McDermott L.C. (1980). An investigation of student understanding of the concept of velocity in one dimension. *Am. J. Phys.* **48**, 1020 – 1028.
15. Watts D.M. (1983). A study of schoolchildren's alternative frameworks of the concept of force. *Eur. J. Sci. Educ.* **5**, 217 – 230.
16. Viennot L. (1979). Spontaneous reasoning in elementary dynamics. *Eur. J. Sci. Educ.* **1**, 205 – 221.
17. Clement J. (1982). Students' preconceptions in introductory mechanics. *Am. J. Phys.* **50** 66 – 71.
18. Gunstone R.F. and White R.T. (1981). Understanding of gravity. *Sci. Educ.* **65**, 291 – 299.
19. Watts D.M. (1982). Gravity — don't take it for granted. *Phys. Educ.* **17**, 116 – 121.
20. Stead K. and Osborne R. (1981). What is friction? — Some children's ideas. *Aust. Sci. Teach. J.* **23**(3), 51 – 58.
21. Minstrell J. (1982). Explaining the 'at rest' condition of an object. *Physics Teacher* **20**, 10 – 14.
22. Posner G.J. *et al.* (1982). Accommodation of a scientific conception: towards a theory of conceptual change. *Sci. Educ.* **66**, 211 – 217.

BEST COPY AVAILABLE

CAI: A Report to the Academy

J. D. Bradley, G. Brink and L. Glasser

The title chosen for this article contains a literary allusion: it is the title which Franz Kafka chose for a monologue, representing a report to an academy by an anthropized ape, regarding his experiences and feelings during his capture and the process of taming and 'humanization'. The monologue is most moving, even terrifying in its implications. We now report to the academy of our peers on the taming of the computer to educational uses; we do not wish to suggest that we are here dealing with a *monkey on the stage* — rather, it is a situation where we have a *tiger by the tail*, and we had better decide rather quickly what to do when we are finally forced to let go!

Innovation in education[1,2]

Education is a difficult task, and the more energetic educators have been accustomed to grab whatever opportunities have come their way, occasionally making great claims for the new procedures, but being warned on all sides of the dangers of their innovations. Thus, Plato railed against writing, for 'if one sees written treatises composed by anyone . . . these are not for that man the things of most worth, if he is a man of worth'. Writing triumphed, nevertheless. But even then its manifestation in printing and textbooks was not regarded by all as an unmitigated blessing; indeed Disraeli claimed that 'the greatest misfortune that ever befell man was the invention of printing'. And so one may continue, through the list.

However, the naysayers were not all so manifestly wrong, for the overriding enthusiasm of innovators has sometimes led them astray, especially when they were so bold as to make all-encompassing claims, such as for the utility of film and television in the classroom. Some went so far as to prepare complete courses on film, hoping, in this way, to overcome the problems of inadequately qualified teachers and of low demonstration budgets. Most educators now recognise film as an adjunct to the teacher, but not a replacement. Another invention for which wild claims were made was the 'programmed learning' or 'teaching' machine of the 1950's, which was to follow Skinnerian learning theory, using instant reward and punishment, and treating the student like a mouse in a maze or a pigeon at a feeding-machine. This, too, was a failure (partly, perhaps, because of the inadequate and inappropriate technology of the time).

Thus, when we come to talk of the computer in education, it behoves us to treat the matter with caution, avoiding extravagant claims, but taking note of the opportunities afforded by the new technology, examining new procedures which it offers us, and adapting teaching and technology to the new circumstances.

The computer's growth in education

The programmed-learning machine and book were the immediate antecedents of the computer as teaching machine. The first group to apply the computer educationally was the computer industry itself, which, starting in the 1950's, trained some of its employees in this way. However, price and programming complexity prevented outsiders from making use of the features of the computer which, even at that time, were recognised as permitting self-paced, individualized instruction with immediate feedback.

Since those first steps there have been two parallel but connected strands of development, which have permitted the computer to enter more generally into education. One strand has been technological development in the computer industry, first leading to larger and more powerful computers which, if such a development had been emulated in the aerospace industry, would provide us with a Boeing which costs R500, and circles the globe in 20 minutes on 20 litres of fuel. Flowing from this and from the space programme, has been the promotion of localized computer power and individual ownership, through the development of the personal computer — as contrasted with the more traditional, 'impersonal', mainframe computer.

The parallel strand of development has been in computer languages. The first languages were at the machine level, accessible only to computer professionals. Later, high-level languages permitted technically qualified outsiders to get their hands dirty, but still acted as barriers to the non-technical. One of the breakthroughs was the development at Dartmouth College of the language BASIC (Beginner's All-purpose Symbolic Instruction Code), in order to introduce undergraduates to the computer by the simplest route. This was so successful that virtually all personal computers today use BASIC as their 'mother tongue'. It may be noted, however, that BASIC is not universally regarded as an unmitigated blessing; the original form was, of course, primitive and this has caused the development of a babel of enhanced, but different, BASICs, each not quite intelligible to the other. Furthermore, BASIC has a primitive structure which leads to poor programming practices, such that even the original programmer may not understand his program after some absence from it.

In order to ease educational programming, a related development has been the appearance of 'authoring' languages, which have structures directed towards instructional use. Unfortunately, they are inherently constraining since they are biased, by their very nature, to a pre-determined mode or philosophy of instruction. Also, the principal authoring languages are now very old and may not take proper account of new developments in computer hardware.

All of this means that it is, at present, rather difficult for the interested, non-computer-expert educationalist to take full advantage of the possibilities that the computer is now able to offer. This problem will, with little doubt, be mitigated in the next few years by the improvement of general knowledge of the computer, making all of us computer-literate. In addition, there will be an improvement of computer languages because computer memory is now so cheap that the controlling language can be expanded to provide more capabilities, without, at the same time, limiting the usable memory.

A place for the computer

The increasing capability and decreasing price of the computer has created a place for the computer in education. Let us examine these capabilities and their educational functions.[2] Where the user and computer face one another, man to machine, there exists the prime capability of individualization of the instruction, at the pace required by the user. This is, perhaps, the most significant development of the computer. By contrast, the more traditional computer mode has been that of batch processing, which is entirely appropriate in production situations, such as for wage packages, accoun-

The authors are in the Department of Chemistry, University of the Witwatersrand, Johannesburg 2001, South Africa.

BEST COPY AVAILABLE

ting systems, and so on, but such a batch mode is *not* appropriate for dialogue.

Dialogue is the most sought-after educational procedure, teacher and pupil using the interaction to probe and to challenge. This ancient procedure, proved effective over many centuries, has been eroded away in the present educational system, where we cannot afford the cost of individualization but must resort to the lecture — so efficient in confronting the one with the many, and even effective in motivation and role-modelling, but poor as a learning aid. The lecture invites the student to passivity, allowing him to act as a channel, a low-quality and noisy recording medium; this is the antithesis of recognized good pedagogical and psychological practice. On the other hand, the user of a good instructional programme is required to be active, but at his own chosen pace, and so is a full participant in the learning process.

The next significant feature of the 'new computing' is the availability of *graphics*[1] — and we take graphics to mean the whole gamut of graphic artifices, such as underlining, textual organization, letter sizing, choice of character set, highlighting, tabulation, super- and subscripting, and so forth (Fig. 1), as well as the more obvious graphs and curves, which may be presented dynamically — rather than as a preset whole. A number of these capabilities were not available (or very expensive) before the advent of personal computers. The first time-sharing computer systems responded by means of the slow, tedious procedure of typing out the information in a linear sequence on a roll of paper. A limited-resolution, character-based, form of graphing was available but did not serve adequately in many situations. One accepted it in the sense that one gapes at 'a dog's walking on its hind-legs. It is not done well, but you are surprised to find it done at all'.[4] Present systems permit the use of quite sophisticated graphics, though the attainable resolution is somewhat reflected in the price of the system; the cheapest systems supply only character graphics (say, 40 × 40 picture elements, or pixels) (Fig. 2), moderately-priced systems provide medium resolution (250 × 200 pixels) (Fig. 3), while the higher-priced systems provide high-resolution (1 000 × 750 pixels), suitable for almost all purposes. The newer systems even offer graphics in colour. The importance of graphics is reflected in the adage that a picture is worth a thousand words. Judging from the appearance of a blackboard after almost any lecture, it would certainly appear that most subjects are educationally enhanced by graphics.

A third development brings the user closer to a real dialogue with the computer. This is removal of the rather laborious, impersonal, and distracting procedure of typing out a response, and replacing that with more direct procedures like pointing with devices such as a 'mouse' (which is rolled across the desk top), a light-pen or, even better, a finger; it is now beginning to be possible to produce an oral conversation (of a limited sort) between user and computer. It is an interesting observation that these sophisticated procedures are more frequently and cheaply available on the independent personal computer systems than on the large, expensive mainframe computers.

Developments presently in the pipeline, but not yet generally available, involve linking the user's computer to other devices which can interact with it. The most direct, a computer-to-computer link, has been available for some time. This permits the user's computer to take advantage of a remote computer's unique facilities, such as a plotter or data bank, or its greater computing power. More recently, it has become possible for the user's computer to control various local devices, the most significant of which are videotape and videodisc.[5] The latter is like a gramophone record, 'read' by a laser beam in place of a stylus, so that it becomes possible to pick out an individual picture or sequence of pictures from the 54 000 which are available on a single disc. Imagine, if the average textbook contains 100 diagrams, then the diagrams from 540 textbooks could be recorded on a single videodisc, any one picture accessible in fractions of a second! Furthermore, the images are not limited to static displays, but video sequences can be mixed in with diagrams, and displayed as required in response to the user's requirements, under computer control. As yet, the interactive videodisc player is quite costly (about the price of a personal microcomputer) and preparation of the material is very expensive, but present developments presage a rapid drop in costs.

The computer in its place

Given all the capabilities which have been described, why should we not expect the computer simply to take over all instruction? Firstly, with all our programming capabilities, it is not possible for the computer to handle unexpected user responses, and the dialogue which we can generate is of very limited scope.

Secondly, the computer cannot simulate the human relationships which are so important in an educational environment: it cannot adapt itself to the circumstances of the moment, sense emotions or even erupt in righteous anger to awaken a recalcitrant to his obligations. Indeed, the computer is just too inhumanly patient! Finally, the computer cannot motivate by example — only the teacher can do that.

CAI in the Chemistry Department, University of the Witwatersrand

Some, or all, of the foregoing, may be familiar to the reader. But, the reader may ask, is it feasible? Can it be made real — now? To this we have an answer: we have created a real, live, actual, working, developing, expanding, innovating computer-assisted instructional (CAI) operation. We have seen the future — and it works! Circumstances placed us in a position where it seemed appropriate and possible to develop a CAI system from scratch, we set about it, and we are now operating at the rate of about 1 000 programs run per week. Thus, we are in a position to discuss problems and procedures from a practical viewpoint, because we have ourselves already faced the problems and established our procedures.

Our plunge into CAI arose from a situation which is by no means unique, and which will be met increasingly across all of education, not only in this country, but elsewhere in the world as well. In the last years,

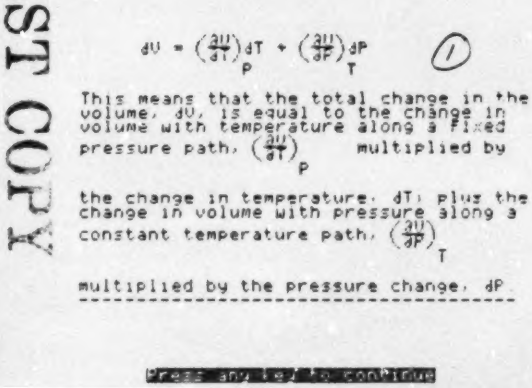
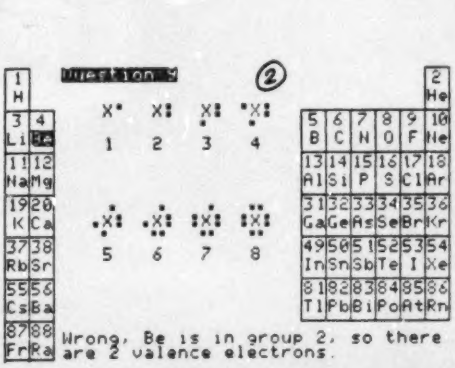

dU = (∂U/∂T)P dT + (∂U/∂P)T dP (1)
This means that the total change in the volume, dU, is equal to the change in volume with temperature along a fixed pressure path, (∂U/∂T)P multiplied by
the change in temperature, dT, plus the change in volume with pressure along a constant temperature path, (∂U/∂P)T
multiplied by the pressure change, dP.
Press any key to continue

Fig. 1 (left). Textual graphics illustrated by screen organization, half-line spacings, special characters, and inverse display.

Fig. 2 (right). Character-based graphics: the fundamental resolution is 40 characters across by 24 lines down.



BEST COPY AVAILABLE

BEST COPY AVAILABLE

students have come into higher education from increasingly disadvantaged backgrounds — as an American educator[6] has remarked, they are older, poorer, and blacker — so that it has become necessary to provide more direct assistance to these students to help them overcome their educational disadvantages and attain their full potentials. Contrary to American experience, we face this problem in a situation of rapidly growing student numbers, poor financing, and a perpetual lack of suitably qualified personnel. The specific situation which required and occasioned a firm decision from us to proceed in a new and largely unknown direction was the introduction of an academic support programme[7] in the university, directed at educationally disadvantaged students.

We decided to approach the challenge by developing a first-year-level, two-year (slow stream) course, a strategy first introduced by our Mathematics Department. We recognised that small-group tutorials (which had been operating in our department for some time), had to be provided, and that, given the shortage of staff, this support could usefully be supplemented by CAI. We could seriously consider this last strategy because we have already gained some experience with microcomputers having adequate graphics capabilities through purchases for laboratory needs in the previous year. We were confident of our programming capabilities because of this experience, as well as the long and detailed prior experience of two of us on mainframe computers, both in scientific computation and in interactive graphics. (In passing, it is interesting to note that such experience with interactive graphics was, and remains to this day, unavailable on many mainframe computer systems.) We had had some preliminary contact with CAI before, but of a very cursory and passing kind. Most important, perhaps, we constituted a group committed to making the necessary sacrifices of time and effort.

We were aware that there was not much software available, but decided to purchase all we could, depending on that to get us started. When it came, we were horrified to discover how poor it was — using all uppercase lettering, incorrect chemical nomenclature (such as unsubscripted subscripts), and unsuitable phraseology. Clearly, this was not suitable for use with already weak and confused students. We, therefore, determined to set our own house in order as well as we knew how, from the very beginning. Since we could not manage the whole job ourselves, we employed students as programmers. Fortunately, we had allowed students open access to our microcomputers during the previous year, and we could find some who had trained themselves; indeed, they were eager to be paid to do what they wanted to do anyway. By dint of much hard work, starting in December 1980, we were able to get the CAI going in February 1981, with a suite of fourteen programs upgraded from those which we had bought.

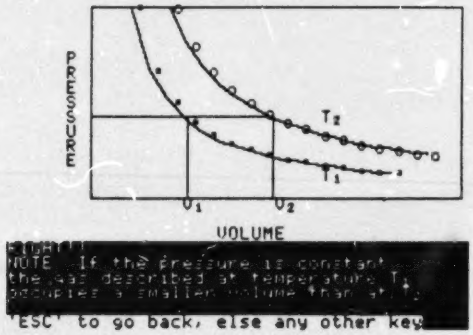


Fig. 3. Medium-resolution graphics, mixed with text. Graphics resolution is 280 × 192 pixels.

The novelty of our offering brought immediate rewards to us in student interest and, encouraged, we proceeded to develop further material. By the end of that first year, about 100 students had run about 6 000 programs on six microcomputers. In the second year of operation 16 000 programs were run on eight microcomputers, and in 1983 we expect to run some 25 000 programs on 11 microcomputers, now serving a group of about 300 students.

We have, at all stages, set ourselves high standards for the CAI presentations, endeavouring to use correct principles of graphic design, to ensure reliable operation of programs, and to provide clear instructions to students.[8] Our success is not measured only by the continued interest of our own students, but also by the fact that our materials have been widely distributed to high schools, technikons, and universities in Southern Africa. At first, we simply donated our material to interested groups but, more recently, we have been forced to request monetary donations in return because the university has not been able to promise continuing support. This support is required for the programming effort — both for development of further material and for improvement of present material — and for the student supervision of the computer resource room.

All in all, we have had the satisfaction of facing and meeting a significant challenge and of receiving recognition by others of our substantial efforts. We are not now ready to rest, because there is a continual challenge to develop new material and to improve our methods of presentation. We have, indeed, sampled the future and know that not only can it work, but that it offers breathtaking educational opportunities.

The content of this article is derived from the text of an address delivered in June, 1983 by L.G. to the Transvaal Branch of the Royal Society of South Africa. The support of the Academic Support Programme of the University and of Deputy Vice-Chancellor P. D. Tyson in the development of our CAI activities is gratefully acknowledged.

1. Bork A. (1981). *Learning with Computers*. Digital Equipment Corp., Bedford, Mass.
2. Taylor R.P. (Ed.) (1980). *The Computer in the School: Tutor, Tool, Tutee*. Teachers College Press, Columbia University, New York.
3. Toong H.D. and Gupta A. (1982). Personal computers, *Scientific American* 247(6), 88.
4. Quoted (out of context) from Boswell's *Life of Samuel Johnson*, 1763.
5. *Creative Computing* (Jan., 1982), 8(1); *Byte*, (June, 1982), 7(6): issues devoted to the interactive videodisc.
6. Hodgkinson H.L., quoted in ref. 1, p. 269.
7. The Academic Support Programme (ASP) staff of the Universities of Cape Town, Natal, the Witwatersrand, and Rhodes University publish a Bulletin, *ASPects*, detailing progress with the ASP (Editorial Office: SH4003, University of the Witwatersrand, Johannesburg).
8. Bradley J.D., Brink G. and Glasser L. (1982). Operational standards in computer-assisted instruction. In *Computers in Education*, edit. D.H. van der Vyver, *Proceedings of SACCE 82*, University of Stellenbosch, Stellenbosch.

BEST COPY AVAILABLE

Computer-managed Instruction on the PLATO System

G. R. Delpierre

In August 1981, the University of the Western Cape installed a mainframe-based PLATO* system serving 64 terminals. This has since grown to an installation with 104 terminals, of which about 80 are available to students. Of the 66 academic departments, 46 are making use of PLATO in some way or another, with varying success. The purpose of this article is to describe a little-known feature of the PLATO system, and its application in a university environment.

The broad features of the PLATO system have already been adequately described in this journal,[1] but in the present climate in South Africa, where exposure to computer-based education (CBE) is on the increase, it should be made clear that two principal modes of CBE can be identified. Computer-assisted instruction (CAI) involves the interaction of the student with the computer, which presents a variety of instructional material such as purely didactic lessons, drill and practice exercises, simulations, games and so on. Several thousands of hours of such material are available on the PLATO system, and most instructional uses of computers in South Africa, whether based on mainframes or microcomputers, are of this kind.

Computer-managed instruction (CMI), on the other hand, manages the instructional process, and, ideally, it caters for every student's individual needs.[2] This is achieved by using the computer to generate diagnostic tests, which are designed to address very specific learning objectives. Should a student fail to achieve a set criterion of proficiency, he is referred by the computer to sources of reference which should assist him to acquire the knowledge necessary to master the objectives on a re-test. In the alternative, if a student performs satisfactorily, he is allowed to proceed to the next series of tests.

Clearly, in CMI, the computer is not necessarily used (as in CAI) as the prime source of information. The sources of reference made available to the student constitute an information bank which can cover a whole university curriculum. This information may be made accessible by a variety of educational technologies, which can include the printed and spoken word. It is not necessary to rely on the existence of any CAI material. A student may be referred to his lecture notes or handouts, to his textbook, or even to his lecturer. In practice, it is advisable to have different media covering a single topic, so that choices of media be made available to students. We have found that in order to get started on CMI, a good textbook is an essential source of reference. Thus, provided a suitable system is available for the delivery of CMI, almost any discipline can be taught in this way at university level. The prime requirement is a computer which can store and retrieve large amounts of data, and integrate the individual student performances in such a way as to allow the instructor easy access to the data.

It is not generally known that PLATO users have access to a complete and highly sophisticated CMI system, known as PLATO Learning Management (PLM).[3] The PLM system can be viewed from three separate aspects, that of author, instructor, and student. The author is the person who creates the testing material. He has at his disposal a truly formidable battery of facilities which enable him to generate questions, design graphics, formulate objectives and feedbacks, decide on scoring methods and testing strategies, and list learning resources. The entire 'authoring' is driven by prompts, and the author need not know anything about programming. This means that a university lecturer, naturally an expert on a particular subject, can be a productive author of CBE material with a minimum of training. Questions can be of six different types: true/false, multiple choice, matching, identifying touch sensitive areas on the screen, numerical input, and short answers. In our experience these question formats can test the majority of learning objectives in chemistry and biochemistry, and a number of other departments, notably German and Accounting, are creating material in this manner.

The instructor or lecturer who makes use of PLM must be prepared to take on a new and exciting role. He no longer needs to spend valuable contact time presenting basic material which is readily available from sources such as textbooks. Instead, he can address specific problem areas which he has identified, and make more use of discussions. By monitoring the progress of the class on the PLATO system, he can have the fullest information on the performance of the class as a whole, or of individual students. He can identify the students who are struggling and help them in an effective way, since difficulties can be clearly identified. What is important is that such difficulties may be spotted early in the academic year, when the students can be helped most profitably.

As far as the student is concerned, he is confronted with a well-defined system of self-study. The student is tested on objectives which are clearly stated. Normally, the instructor will have set options allowing the student to see whether or not he has answered a question correctly, to see the appropriate feedbacks, and the score he has obtained. At the end of the testing episode he will be presented with a list of appropriate references he should consult. If such references include PLATO lessons, the lesson will be presented before the student attempts another test. This is just one example where CMI and CAI work in concert.

The Biochemistry Department at UWC is the largest user of PLATO on the campus, based on hours of on-line time per student per year. The results of the last two years have been very encouraging, with increased pass and reduced dropout rates. This was achieved by substantially reducing the number of formal lectures.[4] This is very significant to all those who are concerned about the lack of trained manpower in South Africa. More specifically, at university, lecturers can be made more effective and have more time available for research. In the end, a university education should equip students to seek information on their own, and to apply it successfully. It is the author's view that CMI can achieve this.

1. Trollip S. (1980). The PLATO computer-based education system. *S. Afr. J. Sci.* **76**, 391 – 393.
2. Allen M. (1980). Computer-managed instruction. *J. Res. Devel. Ed* **14**, 33 – 40.
3. Control Data Corporation (1982). PLATO Learning Management Author's Guide.
4. Delpierre G.R. (1983). Computer-managed instruction at university level. A case study. Paper presented at the IXth International Conference on Improving University Teaching, Dublin, 6 – 9 July.

*PLATO is the registered trade mark of Control Data Corporation.

Professor Delpierre is head of the Department of Biochemistry, University of the Western Cape, Private Bag X17, Belville 7530, South Africa.